Recent Observations of the Spectrum of *Mars*, by W. W. Campbell.

"In the year 1894, I described for the *Chronicle* my observations of the spectrum of *Mars*, and stated the conclusions to be drawn from them concerning the presence of atmosphere and water on that planet. The observations were made by visual methods entirely. In the spring of 1895 and the winter of 1896–97, I repeated the observations, making them by photography. Professor Keeler of the Allegheny Observatory (formerly of the Lick Observatory), recently wrote me that he also had observed the spectrum of *Mars* photographically in the last few months, and I have his permission to describe his results along with my own. Our work has an important bearing on the question of *Mars*' atmosphere and the conditions of life on that planet, and I take this opportunity of making it public. * * *

"The problem was attacked in the years 1862–77 by Huggins, Janssen, Vogel, and Maunder. All came to the conclusion that the spectroscope was able to detect evidence of atmosphere containing water-vapor. Their results supported the popular side of the question, and were accepted without reserve. Their observations were nearly all made under extremely unfavorable circumstances: with *Mars* near the horizon, with small telescopes, at stations near sea level and in very moist localities. I feel sure that the observers themselves would now be willing to say that much of their evidence was very discordant, and in some points it was erroneous. A case in court, based on similar evidence, would be dismissed, with costs levied on the plaintiff.

"While I believed that the early observations, though weak and discordant, were essentially correct, it seemed to me well worth while to repeat them at Mt. Hamilton, on account of the favorable circumstances of position and climate existing here. Among the advantages existing here may be mentioned: 1. A more powerful telescope and spectroscope. 2. The altitude of the observatory, eliminating the lower 4200 feet of atmosphere and its aqueous vapor. 3. The southern location of the observatory and the northern position of *Mars* in 1894, bringing the planet nearer the zenith. 4. The very dry air existing here in the early summer. With these and other favorable circumstances, I expected that a confirmation of previous results would be a simple and easy matter. Accordingly, I compared the Martian

and lunar spectra on several nights in 1894, when our atmosphere was remarkably dry, and the two bodies were at equal altitudes above the horizon. At all times the spectra of the two bodies appeared to be identical in every respect. The oxygen and aqueous vapor lines were stronger when the Moon and planet were near the horizon than when they were near the zenith, for the obvious reason, that in the lower positions the rays of light traversed the greater depth of our atmosphere. In fact, an increase of twenty-five to fifty *per cent.* in the length of path in our atmosphere seemed sufficient to change the spectrum appreciably.

"The conclusions to be drawn from the observations are very simple, yet they have been widely misunderstood. They are: 1. The observations furnish no evidence of the existence of a Martian atmosphere containing aqueous vapor. 2. They do not prove that *Mars* has no atmosphere, nor do they even suggest that idea. They simply set a limit to the possible extent of the atmosphere, or, rather, to the quantity of oxygen and aqueous vapor contained in it. The light coming to us from *Mars* has been reflected from the planet's surface, or from the inner strata of its atmosphere, and has, therefore, passed twice, either completely or partially, through its atmosphere. If an increase of twenty-five to fifty *per cent.* in the length of path of the rays in our atmosphere changes the spectrum appreciably, the Martian atmosphere should have been detected, if it is one fourth as extensive as ours. 3. We know, from the waxing and waning of the polar caps with the advent of winter and summer, respectively, that *Mars* has some atmosphere and some vapor analogous to our water-vapor, but we do not know how much. They do not seem to exist in sufficient quantities to be detected by spectroscopic methods; that is, they do not seem to be more than one fourth as extensive as on the earth, and they may be considerably less.

"As soon as my 1894 results were published, Messrs. HUGGINS and VOGEL repeated their observations of 1867 and 1873, respectively. Both were very positive in the early years that *Mars*' atmosphere and aqueous vapor were very easy to detect, and must, therefore, be of great extent. They were able, in 1894, to confirm their early work in some points, but in others they were not. This is not the place to make a scientific criticism of scientific results, but it should be stated that at the points in

the spectrum where HUGGINS said the aqueous vapor lines were stronger in *Mars* than in the Moon, VOGEL said no difference could be detected by him; and in the case of the vapor lines in another place in the spectrum, which VOGEL said were stronger in *Mars* than in the Moon, HUGGINS did not detect any difference. The two distinguished observers did not agree with each other in even a single point.

"As stated above, the 1894 results were arrived at entirely by visual methods. The past winter, Professor KEELER and I, working independently, repeated my 1894 work, using the photographic method. We photographed the spectrum of *Mars* and the Moon when these bodies had equal altitudes. After a few trials, it was easy to determine the exposure time necessary to make the two photographic images of the same density. When the negatives were developed, it remained only to compare the spectra to detect any differences that might exist. Neither Professor KEELER nor I was able to detect the slightest difference between the spectrum of *Mars* and that of the Moon. (It should be said that the aqueous vapor lines most studied by the various observers lie in the yellow and orange of the spectrum, and to record them photographically it was necessary to use orthochromatic plates. The oxygen lines lie wholly, so far as we know, in the red, and could not be photographed satisfactorily. The investigation applies, therefore, only to the aqueous vapor lines.)

"Professor KEELER considered that if the Moon moved from the zenith down to an altitude less than forty-five degrees, its spectrum underwent appreciable changes: the vapor lines were the stronger in the lower position of the Moon. My estimate of the sensitiveness of the method was practically the same, or a trifle less, than KEELER'S. Now, the length of path in our atmosphere traversed by the Moon's rays, when at an altitude of forty-five degrees, is forty *per cent.* longer than when the Moon is in the zenith. Again we confirmed my visual results of 1894, since I then found that twenty-five to fifty *per cent.* increase in the length of path produced an appreciable change in the spectrum. Recalling that the light coming to us from *Mars* has passed twice, either completely or partially, through that planet's atmosphere, we arrive again at the result that the water-vapor there is not more than one fourth as extensive as on the Earth. (In speaking of 'extensiveness,' I mean the absolute quantity

of vapor above a given area — a square mile, for example — of the planet's surface.)

"Having been led, by the observations of 1894, to take the unpopular side of the question, *viz:* the oxygen and water-vapor (or some other vapor analagous to water-vapor) in *Mars*' atmosphere are of slight amount, probably not more than one fourth as extensive as on the Earth, — I may be pardoned for saying it is a pleasure to have so able and conscientious an observer as Professor KEELER write: 'No doubt you are entirely correct on the water-vapor question.'

"Assuming that the chemical constituents exist in the same proportions in the Earth's and *Mars*' atmospheres — we cannot say that they do — what would be the density of *Mars*' atmosphere at the planet's surface? If there is not more than one fourth as much atmosphere above a square mile on *Mars* as there is above the same area on the Earth, its density at the surface of the planet would be less than one eighth the density of our air at sea level; that is, it would be less than half as dense as the atmosphere at the summit of Mt. Everest. Such being the case, the conditions of life on the two planets would no longer be comparable. Astronomers would wisely turn the question of life on our neighboring planet over to the physiologists for solution; and possibly the latter would wisely hand it over to the domain of pure speculation for the present." —From the S. F. *Chronicle*, April 25, 1897.